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screwed to the front edge of the cradle; under these the plate *z* can slide up and down, the screw 1 serving to bind it fast. The plate *z* is bent at right angles, having on it a dovetail, in which the plate 2 can slide, right or left, and the screw 3 serves to bind it fast. The object-end of the finder passes through the hole 4, whilst the front end lodges in the sliding-plate 2; hence it can be moved to agree with any telescope. The telescope being directed to a distant object, the cross-wires of the finder are brought on the same, and then both instruments will be parallel.

No. XVII.

MACHINE FOR GRINDING AND POLISHING LENSES AND SPECULA FOR TELESCOPES.

The Large Gold Medal was presented to Richard Greene, M.D., of Cork, for his Machine for Grinding and Polishing the Mirrors of Telescopes and Lenses for Achromatic Object-Glasses, a Model of which has been placed in the Society's Repository.

32 *Cirencester Place, Fitzroy Square,*
March 31*st*, 1834.

Sir,

The model which I have the honour to lay before the Society is of my own construction, and being made up in great haste, is not as exact as I could wish in the proportion of its smaller parts, and the diameter of the fly-wheel is fully one-fourth less than it should be, from my not having a larger one at hand; it, however, accurately represents the different motions the mirror undergoes in the process of being polished.

The general scale of the model is one-fifth of the lineal dimensions of the largest working machine I have as yet constructed, and which I find amply powerful for a mirror of *nine inches diameter*.

In presenting this my invention to the public, through the medium of the Society, I do not offer one of those visionary schemes, the offspring of a heated imagination, which too generally perish shortly after their premature birth, when subjected to the severe test of practical application. With these machines (I have them of different sizes), I have polished and repolished mirrors of various diameters, from three to nine inches, for telescopes of the Newtonian and Gregorian construction; and from the clean and perfect separation of ε Boötis, the division in Saturn's ring, and other minutiæ of astronomy, which I have observed with my telescopes, it must be inferred that the figure of the mirrors was exquisitely perfect.

Description of the Machine which I employ for my Nine-inch Specula.

Length of the frame *a b*, Plate IV., fig. 1, five feet. The two long bars *c d* are 2½ inches broad by 3½ inches deep, and are nine inches asunder on the inside; the machine stands upon four legs, 2½ inches square, which raise the upper face of the bars 15 inches high. The cross-piece *a*, through which the mandril *e* passes, is 2 feet 8 inches long, 4½ inches wide, and 2½ deep; the cross-bar *b* at the other end is 20 inches long, 3½ wide, and 2½ deep. The square board *ff*, which carries the pillar *g*, is 12 inches square, and 1½ thick, and is firmly fixed by seven screws to the upper surface of the cross-piece *a*, and of one of the long bars, as is plainly seen in the figure. This board covers one part of the bar and part of the cross-piece *a*, to their edges; it stands 1½ inch above the level of the frame, and firmly binds the long bar *d* to the cross-piece *a*. The legs are firmly mortised into cross-pieces at the bottom, 2½ inches wide, and 1½ thick. The mandril *e* is 14 inches long, 1½ diameter at its shoulder, tapering gradually to ¾ inch at the lower end, in which there is a small hole drilled to rest upon a pointed screw of hard steel *h*, which is attached to the lower cross-piece. The upper part of the mandril works in a bell-metal collar let into the upper cross-piece *a*, and on a level with its upper surface: the mandril is to be ground into this collar, until its shoulder shall stand only ¼ inch above the surface of the frame; the mandril shall stand truly perpendicular, and at the distance of about 1 inch from the leg of the machine. The screw of the mandril may be about ¾ inch in diameter, and as much in length. The bell-crank *i* has each arm 9 inches from the centre of motion to the joints of the connecting rods *j k*; it works upon a steel arbor, which passes through the pillar *g*, which is to be firmly fixed near one corner of the square board *f*. This pillar is 2½ inches high; the crank is secured by a nut, and is to be ground on the arbor, so as to have a very smooth and steady motion. The double joints of the connecting rods *j* and *k* are each formed of one piece of metal, of the form represented: one cut receives the end of the arm of the bell-crank *i*, while the other cut receives a steel plate *l*, which is riveted into the end of the connecting rod *k*: this forms a steady universal joint when steel-pins are put into the holes. The fly-wheel *m* is 26 inches diameter, and weighs from forty to fifty pounds. The screw upon the end of the mandril is destined to receive a disc or chuck of cast-iron 7 inches diameter, 1 inch in thickness at the centre, and gradually decreasing to ½ inch at the edge, having its upper surface quite flat. Upon the flat surface of this chuck, the pewter polishing-tool is fixed with six common 1¼ inch screws, which pass through the chuck, in which there are six holes near the margin, and screw into the pewter. The margin of the pewter polisher is elliptical, 10 inches by 9, and 1½ thick. Between the chuck and the polisher, a circular disc of sheet lead *n*, 15 inches diameter, is to be interposed; its edge is to be turned up into the form *n*, exactly resembling a common frying-pan, about 1 inch deep, and 12 or 13 diameter; it is to retain the mud that is formed in grinding or polishing, and it thus keeps every thing clean. To the under surface of the chuck, a brass ring 7 inches diameter outside, 5½ inside, and ⅜ thick, is to be fastened with six screws; and when on the chuck, and the chuck on the mandril, its edge is to be turned with a groove, like a pulley, in which a screw of about ten threads to the inch is to be cut. The face of the pewter polisher is also to be turned to the degree of convexity required, after it is affixed to the chuck. An endless screw *o* runs in this pulley, and gives a slow rotation to the chuck and its polisher. This screw is of steel hardened and tempered, and by notching three or four threads at its end like a tap, it will cut the pulley in its place: when it is cut, by moving the bearing in which the other end of the screw runs, about an inch nearer the pulley, the smooth part of the screw will now take in the pulley, and cause it to revolve. The screw receives its motion from a pulley *p*, 4 inches diameter, fixed upon its axis or shank, and a band which also passes over the small pulley *q*, of 2 inches diameter, upon the axis of the fly. The fly is moved by a pulley *r*, 4 inches diameter, which corresponds with the wheel *s*, 12 inches diameter, on the axis of which is the winch-handle *t*, which gives motion to the entire. This same axis has a second pulley *u*, 6 inches diameter, which turns the pulley *v*, 12 inches diameter; and upon its axis are two other pulleys *w*, 9¾, and *x*, 7½ inches diameter. The axis of these three pulleys is raised 4 inches above the level of the frame by two solid blocks: one, *y*, only is seen. One of the legs *z* of the frame is longer than the others, and projects six inches above its upper surface. A groove is to be cut in its top, to allow another axis 1 to rest in it 5 inches above the frame. This axis is supported horizontally by a pillar 2, in the model; but it would be more simple to make the other leg as long as the leg *z*. On this axis are two more pulleys, 3, 9 inches diameter, opposite to *w*, and 4, 11¼ diameter, opposite to *x*; so that the same band can be passed from one pair of pulleys to the other pair in an instant, without making any alteration in its length.

The pulleys are all formed of three pieces, to prevent warping, viz. a ¾-inch plank in the middle, having a ⅜-plank glued on each side of it, with the grain of the two latter at right angles to that of the former. When dry, let them be wedged with glue upon that part of their axis where they are to remain, and let them be turned on their axis, with their edge a little convex, which form has the property of preventing the band from slipping off. A strip of woollen cloth glued on the edge of the pulleys will increase the adhesion, and allow you to work with looser bands. The axes are formed of ¾-inch square bars of scrap-iron, and require no forging. The bands may be made of buff-strap, or of such leather as the saddlers employ for stirrup-leathers, and should be fully an inch broad, and put on pretty tight. The pulleys Nos. 1 and 2 need not be more than an inch in thickness, and their band of ½-inch broad basil may be left very loose. The pivots of all the axes run in boxes or bearings of box-wood, and are screwed up pretty tight. These are easily made, and I find give a very smooth motion, little disposed to heat, wear, or dirty the oil, and are far preferable to brass or bell-metal.

Upon the projecting extremity of the axis 1, which carries the pulleys Nos. 3 and 4, is fixed a strong straight crank 5, shewn larger in fig. 2, about six inches long, and graduated on its face to tenths of an inch. On it slides an iron-box or square tube 6, having the outer side 6 projecting so much beyond the other three sides towards the centre of motion, that a steel stud 7 affixed to it can be made to slide over the centre of the axis 1, or be placed at any required distance from it, and be kept in its place by the pressure of the screw 8, which passes through one side of the box, and bears upon the crank 5, thus rendering the length of the crank variable at pleasure, and capable of being altered in a few seconds. On the base of this stud 7 is a fast pulley 9, one inch diameter, and having a deep V-groove in it: the rotation of this pulley gives rotation to the mirror. On this stud hangs the connecting-rod 10, 10, fig. 1, which is attached to the back of the mirror. A nearly similar crank 11, is upon the end of the axis which carries the pulleys *v*, *w*, and *x*, but at the opposite side of the machine. The only difference between them is, that the sliding-box of the crank has no pulley upon its steel stud, which receives the connecting-rod *k*, giving motion to the bell-crank *i*. The connecting-rods are attached to the cranks in the following manner: — A hard steel plate of the form 12, fig. 3, is firmly screwed or riveted to the side of the wooden connecting-rod 10, next to the crank. It is the notch of this plate which hooks upon the neck of the stud 7, which should fit each other accurately. The plate 13, which revolves round a screw on the under side of the connecting-rod, being pushed under the stud, keeps the plate 12 in its place, and prevents it from unhooking. This is a convenient mode of fastening the rod 10, 10, in particular, as it frequently requires to be detached very quickly in the act of polishing.

To give Motion to the Speculum.

Let a back (as it is called) be prepared of hard pewter, two-thirds the diameter of the speculum, and for a 9-inch mirror, fully half an inch in thickness at the centre, and decreasing gradually to one-eighth of an inch at the edge. Let its under surface be turned as nearly as can be to fit the back surface of the mirror. A female screw, 1½-inch diameter, is to be turned in its centre quite through. This back is afterwards to be cemented upon the mirror with soft pitch, and its centre should accurately coincide with the centre of the mirror. A brass handle is to fit into the screw of this pewter back. It is of the form represented in fig. 4: the screw 14, half an inch long, and 1½ diameter; the flanch 15, 2¼ diameter, and ⅛ in thickness; the cylinder 16, 1½ in diameter, and ½ long; a square prism 17, the largest that can be formed out of the cylinder, and an inch in height. On the top of it stands a screw 18, half an inch in diameter, and an inch in length. This handle is to be screwed tight into the pewter back before it is stuck on the mirror; and a circular disc of thin paper should be pasted on the end of the screw, so as to cover the joint, to prevent the pitch from entering it, which would render the removal of the brass handle a matter of difficulty. The cylinder 16 of the handle receives the rings of the two connecting-rods 10, 10, and *j*, and their form is easily understood by referring to fig. 5: a ring of stout sheet-brass, 2 inches in width, and nicely fitting upon the cylindrical part of the handle, is represented by 19. A hinge 20, to allow the ring to follow the curvature of the polisher, terminates in two plates of brass 21, 21, which are firmly riveted to the wooden connecting-rod 10, 10. The length of the connecting-rods must be such, that when the studs of the sliding-boxes of the two cranks are placed over the centres of their respective axes, the sides or arms of the bell-crank shall be parallel to the sides of the square board on which it stands; and the centres of the two rings of 10, 10, and *j*, shall both coincide with the centre of the polisher when they are put upon the cylinder of the brass handle, which is screwed into the pewter-back attached to the speculum. A washer of fine card should be interposed between the flanch of the handle and the ring next to it; another between the two rings, and a third between the upper ring and the wooden pulley 22, which keeps the rings in their places, and gives rotation to the mirror. This pulley should be made of light wood, 14 or 15 inches diameter, and ⅜ in thickness at the edge, in which a deep V is to be cut, but strengthened in the centre by a piece of hard wood making its centre there fully an inch, gradually tapering off so as to support about six inches of its centre. This pulley fits upon the prism of the brass handle, and is fastened down by a circular nut of box-wood, which screws upon the upper or smaller screw of the handle. It is seen in its place fig. 1, 22. It receives rotation from the fast-pulley 9, attached to the stud 7 of the variable crank 5 by a gut-band 23, 23; 24 is a small guide and tightening pulley, of 2 inches diameter, on one end of a flat strip of brass about 6 inches long; the other end of which is fastened by a screw to the upper part of the connecting-rod 10, 10. This bar moves stiffly round the screw, and will remain at any angle to which it is set.

Action of the Machine.

The action of the machine can now be easily understood. If either of the cranks be shortened to nothing by fixing the stud in the centre of motion, the other crank will cause the mirror to move backwards and forwards with cross strokes over the centre of the polisher; while the polisher revolving slowly in one direction, and the mirror in an opposite one, the different parts of each will have their relative positions perpetually changing. The extent of the stroke given by each crank will be double the length of the crank; and this is altered in an instant by sliding the box with the stud upon the crank.

Let us now suppose both sliding-cranks set to the same length, and the band passed over the pulleys *w* and 3, of 9¾ and 9 inches diameter, and suppose their cranks, at any moment of time, to be vertical, and of course at right angles to their connecting-rods; now, as their motion is so nearly equal, they will remain nearly parallel to each other for one revolution, and their joint action will be to cause the mirror to move in the diagonal of the two forces, and it will describe two cross strokes in nearly a straight line over the centre of the polisher. When, however, the pulley *w* shall have described three revolutions, the cranks, which were at first parallel, will now be found at right angles to each other. The effect now produced will be, that one crank, at right angles to its connecting-rod, will propel it with its greatest velocity; while the other crank, parallel to its connecting-rod, gives it scarcely any motion; and the mirror being at this time at its greatest distance from the centre of the polisher, the first crank, acting upon it at right angles as a continually deflecting force, will cause it to describe a curve nearly circular around the centre of the polisher. At every revolution, this curve approaches the straight line or transverse stroke over the centre of the polisher; and at the end of three more revolutions of the pulley *w*, it will again give a stroke nearly transverse, which will again gradually change into a curve in the opposite direction.

If the band be now passed over the pulleys *x* and 4, of 7½ and 11¼ inches diameter, the changes from curves to a position of a straight stroke succeed each other so rapidly, that the path of the mirror will in some degree resemble a capital L in writing, which being frequently repeated, will cover the polisher in every direction.

In the above instances, we have supposed the two cranks of equal length; but it is obvious, that by varying their proportion to each other, an endless variety of curves can be produced.

Were it desirable to polish by circular or elliptical strokes round the centre of the polisher, it could easily be effected by having two more pulleys on the arbors moving the cranks, each being 9⅜ inches diameter. As the two cranks would now move with equal velocity, by setting them at right angles at starting they would retain their relative position; and if their length were equal, the centre of the mirror would move in a circle around the centre of the polisher; but if the length of the cranks were unequal, its path would be an ellipse.

Path described by the Mirror.

For the use of those who have not had an opportunity of seeing the machine, or model, in action, I have traced a few diagrams, describing the path of the centre of the mirror over the surface of the polisher. This was effected by fixing a piece of card pasteboard in the place of the polisher, and uniting the two connecting-rods upon a piece of tube which allowed a pencil to pass through it freely yet steadily, and the pencil was loaded with a weight sufficient to cause it to trace.

In forming fig. 6, both cranks were fixed parallel to each other, and vertical, which placed the pencil on the centre; one quarter of a revolution of the cranks carried the pencil to 25, which is nearly a straight line. At 25 it turns sharp, and traces the line to 26 somewhat curved. It then returns through another curve, and back again through a line still more curved than any of the preceding; and thus its path may be traced by the lines in the figure. When arrived at the fifth and sixth line, it will be seen that the curves are nearly circular, as the cranks are at this time at right angles to each other. The curves now begin to close in a direction at right angles to the first line; and by the eleventh or twelfth turn of the cranks become very elliptical, and at last nearly straight, the cranks having again become parallel; and the machine was stopped when the pencil came to the centre. The ratio of the diameter of the pulleys moving the cranks was about that of 23 to 24, and the cranks were of equal length. This I call the primitive figure of that ratio.

Were the machine continued in action for as many more revolutions, a similar figure would be repeated, but not exactly in the same place, except the cranks became parallel precisely at the time of their being horizontal, which is very unlikely to happen.

As both arms of the bell-crank are equal, the distance 26–27 will be twice the length of one crank, and the distance of 26–28 will be twice the length of the other crank; and those strokes which are nearly circular will have a diameter equal to those lines; but the very elliptical or transverse strokes will be to twice the length of the cranks as $\sqrt[2]{2}:1$, or as the diagonal of a square to one of its sides. This must never be lost sight of in calculating the length of stroke which one may wish to give to the mirror in polishing, as it is well known the length of stroke always commands the figure.

Similar reasoning is applicable if the cranks be unequal, when one crank is double the length of the other. The lines will be similar to fig. 6, but included in a parallelogram, whose sides are as 1 to 2. In this diagram the ratio of the pulleys is also as 23 to 24. These two diagrams were traced with a five-feet machine.

Those who are practically acquainted with the effects produced upon the figure of mirrors by a difference in the method of working, will readily perceive, that any of the conic sections which have hitherto been produced by hand-polishing, can with this machine be effected with far more certainty and regularity, as it is not possible for the most experienced workman to calculate the length of stroke he employs in polishing by hand. Nor is this all: heat partially applied has a surprising influence upon the figure of a mirror; and it is quite impossible to allow for the effect of that which is communicated by the hand when it is directly applied to the mirror; and the unequal pressure of the hand (which no care can prevent), I believe, often causes the vertex of the parabola to be found in some part of the mirror different from its centre.

As it is my intention at some future, and, I hope, no distant period, to lay before the Society an essay on polishing and figuring mirrors, with the formation of the polisher, preparation of the powder, temper of the pitch, effect of different velocities, of different-sized and shaped polishers, and of the variations produced upon the figure of the mirror by the different motions of the machine, I shall at present give only a few practical hints, for the guidance of those who may feel disposed to try polishing by the machine.

In the first place, the temper of the pitch is of primary importance, and it should be such that the cross furrows made in it should, at the end of four or five hours' polishing, be diminished in their breadth by about *one-third* part, and *not more*, or the pitch will, if so soft, never figure a mirror capable of giving a sharply defined image, although its general figure may appear parabolic, and its polish most exquisite. Secondly, I would advise keeping the polisher always moist, never allowing it to get nearly dry, as is the usual practice with workmen, to obtain a fine polish. This is done to prevent the extreme trouble attending the preparation of a powder of the necessary fineness for wet-polishing. To procure such a powder, after long-continued trituration of colcothar or red oxide of iron, in a mortar of porcelain or agate, I float off the finer parts with water, in the usual manner, returning the coarser into the mortar. I then mix all the fine powder thus washed over in a tall cylindrical jar of thin gum-water; this will keep the very fine particles suspended for a long time, and allow the heavier to fall to the bottom. The upper portion of the gum-water is then, at a proper time, to be carefully decanted off into another vessel; and, on being further diluted with water, it will, after two or three days, deposit a powder so fine that it may be applied to the last moment, if necessary. Having coated the polisher pretty freely with colcothar washed over with water in the usual manner, I work the mirror for an hour and a half, or two hours. I then wash it and the mirror well with a flat camel-hair brush and water of the exact temperature of the polisher. I then apply the very fine powder I have described, and wet occasionally with a solution of carbonate of soda, in the proportion of five or six grains to the ounce of water; this removes the harshness of the surface of the pitch, without injuring its figure, as an increase of temperature always does. Thirdly, to insure a regular fine figure it is necessary to alter the length of the cranks whilst the mirror is being polished. This I consider the most important and most essential part of the process. The mirror should be polished partly by very free and bold strokes, partly by very short, and partly by those of an intermediate length. To ascertain how frequently and to what extent these changes should take place, is a very complicated subject, of most difficult investigation, and one on which I can at present speak with little confidence; but the relative length of the two cranks I would advise to be always kept between 3 to 2, and 2 to 1. Fourthly, the polisher should always be surrounded with a sufficient quantity of water in the leaden pan to cover the bulb of a small thermometer, as pitch is so much affected by a small variation of temperature, that should any considerable change occur during the process, it is in vain to look for any good result. Fifthly, great attention should be paid to the velocity of the mirror; forty or fifty strokes a minute, if the strokes be long in proportion to the diameter of the mirror, or from fifty to sixty, if they are short, is as rapid a motion as ought to be employed; if quicker, it will heat the surface of the pitch, and distort the figure of the mirror almost as much as the heat of the hand in hand-polishing, although the error produced will be in the opposite direction.

I am, Sir, &c. &c.

A. Aikin, Esq. RICHARD GREENE.
Secretary, &c. &c.

P.S.—Since writing the above description, I have been engaged in assisting my friend, Captain H. Kater, to get constructed a polishing-machine of five feet in length. This gentleman, well known to the philosophical world as a zealous labourer in many departments of science, the inventor and improver of numerous instruments, has devoted considerable attention to polishing mirrors, and particularly through the medium of machinery. On attentively examining the path of the mirror over the surface of the polisher, which it traverses in every possible direction, it occurred to him that it may not, perhaps, be necessary that the polisher should *continually* revolve. I fully coincided in his view of the subject, and subsequent experiments have confirmed the correctness of his opinion. This suggestion very considerably simplifies the construction of the machine, and, I believe, without any injurious effects upon its action. The rotation of the polisher is produced by several parts of the machine which are by far the most troublesome to execute in its entire construction; and that motion not being necessary, disencumbers it of the following parts:—the mandril *e* and its collar, its large iron chuck which carries the polisher; the large brass ring, having a screw cut at its edge; the endless screw *o*, with its pulley; the pulley *q* on the axis of the fly-wheel, and their band.

In place of this apparatus we simply fixed a piece of inch plank, one foot square, firmly to the frame by four screws, with its centre in that part of the upper cross-bar through which it was intended the mandril should pass, in case we found it necessary to employ one. Another square piece of plank, of the same dimensions, was fixed upon the first plank by one strong screw passing through both their centres, in such a manner that the upper plank can be turned at pleasure, by the hand, around this screw as an axis; and it moves so stiffly that it will remain in any position in which it is placed without danger of turning by the action of the mirror. To this upper plank the polisher and its leaden tray are fixed by four common screws. As the mirror is being polished, this plank is occasionally, every fifteen or twenty minutes, turned round one quarter of a revolution; or the upper board may be round, and shave the tangent-screw, as in fig. 1, to keep it moving, its motion being so very slow. A mandril, though perhaps best, is not absolutely required to render that motion smoother.

The next point for consideration is the mode of attaching the apparatus to the mirror; and this, I may observe, is of the greatest importance towards obtaining a satisfactory result with certainty.

That many a fine mirror has been destroyed by separating the back, is a fact well-known to every person who has ever embarked in the delicate and often vexatious operation of figuring specula. If a mirror be bound, pressed, or restrained in any way, by even a very small external force, while in the act of being polished, whatever figure it may in that state acquire will be changed to some other curve the moment it is released from that force.

So delicately sensible are mirrors, that the slight blow required to detach the back, if cold, or the annealing process they must undergo to melt the pitch, if heat be employed, I suspect may suffice to injure an exquisitely fine figure. For this reason I always leave attached to a fine Newtonian mirror the back with which it was polished.

To remove this source of error and uncertainty, Capt. Kater attached the apparatus to a loose back of strong tin, having a ring round it, exactly like the cover of a common round tin canister; the ring being rather less deep than the thickness of the mirror, so as not to touch the pitch. The ring should be so much larger than the mirror that, when lined inside with soft leather, it may not press upon the edge of the mirror in any direction.

This method rotates the mirror perfectly well; and the ring will not rise up in polishing, if the edge of the mirror be perpendicular to its face. If the mirror be much bevelled at the edge, the apparatus must be cemented to it with pitch; but in this case I would advise a disc of soft and thick buck-skin leather to be interposed between them, taking care that the heat employed to cement them be so moderate as only to soften, not to melt the pitch, so that it may not enter the substance of the leather to harden it, but allow a slight motion between the mirror and the back.

I am perfectly convinced, that a loose cover, such as

I have described, having the pulleys 9 and 22 and cord-band 23, as in fig. 1, affixed to it, would rotate the mirror as well as the method I have hitherto employed, provided the edge of the mirror be without bevel; and if, in any case, a back is to be cemented to a mirror, I would always advise a piece of soft leather to be interposed to prevent any strain between it and the pewter back.

CORRIGENDA IN FIRST PART OF VOL. L.

Page 11, 5 *lines from bottom*, *for* height, and place the connecting bar *g*, *read* height and place, the connecting bar *g*.
13, *line* 2, *for* ; then unclamp *read* , first unclamping.
14, 5 and 8, *for b read l.*
— 16, *for* lie *read* lies the bar.
26, 8, *after* grs. *add* of morphia.
33, 16, *dele* working.
39, 3, *for* latter *read* former.
— 10, *after* to *add* air and.
53, 8, 11, 27, 31, *for* bar or bars *read* arm or arms.
— 14, *for* 2 *read* 1.
55, 21, *dele* subsequently.
57, 14, *dele* and.
58, 3 *from bottom, for c c,* which is a front, *read* which is a front view, *c c.*
59, 5 *from bottom*, *dele* thrown back and, *and insert the same in the next following line*, *after* compartment.
63, 5, *for* covered *read* high-pressure.
69, 5 *from bottom*, *for* right angles *read* the angle.
84, 9, *after* horns *insert e.*
86, 12 *from bottom*, *dele* (as in figure 15).
90, 1 *and* 2, *omit* alternate.
— 6, *omit* half the planks retain their original thickness, and.
— 9, *omit* half.
91, 6 *from bottom*, *after* separate *add* in perspective.
—, *last line*, *after* Fig. 1 *add* the two other arms of this knee are horizontal, and at right angles to each other, one of them being parallel to the side of the ship, and the other perpendicular to it.
99, *last line*, *for* 1 *read* 2.
100, *line* 1, *for* 2 *read* 1.
108, 6 *from bottom*, *read the first part of this sentence as follows:* A straight bar projects from the hinder part of the plate *f*, and to this is attached a crank *g* in such a position that the end of its lower arm shall move vertically whenever the bar attached to *f* is moved horizontally.
109, 4, *for* ring, *twice repeated*, *read* swivel.
110, 23, *for the sentence* the weight *to* end of *g*, *substitute* the weight *l* on the spindle *i* balances the spiral *m*, the weight *o* on the crank balances the copper plate and horizontal bar, and another weight at the right hand end of the bar *g* (not shewn in the engraving), balances the weight of the wire.
144, 4, *after* entire *add* machine.
155, 11 *from bottom*, *for* shave *read* have.